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Accepted Manuscript

Laparoscopy has a therapeutic role in the management of abdominal trauma: A matched-pair analysis

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Title Page

Title: LAPAROSCOPY HAS A THERAPEUTIC ROLE IN THE MANAGEMENT OF ABDOMINAL TRAUMA: A MATCHED-PAIR ANALYSIS

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Abstract**INTRODUCTION:**

Laparoscopy is increasingly utilised as a diagnostic tool in management of abdominal trauma; however its role in therapeutic intervention remains unexplored. The aim of this study is to compare laparoscopy with laparotomy in the treatment of abdominal trauma in haemodynamically stable patients.

METHODS:

A review of patients undergoing surgery for abdominal trauma between January 2004-2014 identified 25 patients who underwent laparoscopy for therapeutic intervention (TL). This group was matched with 25 similar patients undergoing laparotomy (LT). Matching of the two cohorts was based on patient characteristics, severity of injuries, haemodynamic compromise and radiological findings. Peri-operative outcomes were compared.

DISCUSSION:

Patient characteristics were similar in TL and LT patients for age (median 33 vs. 26 years), gender distribution and clinical presentation. Injury severity score was also similar with a median of 16 in both groups (major trauma=ISS>15, normal range 0-75). Types of injuries included; hollow viscus [bowel repair = 10 (TL) vs. 17 (LT)] and solid organs [5(TL) vs. 2 (LT)].

Median operating time was similar in both groups; 105(TL) compared to 98 (LT) minutes ($p=0.09$). Post-operative complications (1 vs. 10, $p < 0.001$), analgesia requirements, specifically opiate use (34 vs. 136 morphine equivalents, $p<0.01$) and hospital stay (4 vs. 9 days, $p<0.05$) were significantly lower in the laparoscopy group.

CONCLUSIONS:

Abdominal trauma in haemodynamically stable patients can be managed effectively and safely with laparoscopy by experienced surgeons. Major benefits may include lower morbidity, reduced pain, and shorter length of hospital stay.

The management of abdominal trauma is continuously evolving. Improved imaging techniques and better understanding of physiology has helped decrease the burden of morbidity in these patients.

Where earlier, laparotomy would be used as a diagnostic and therapeutic tool, increasingly conservative measures are adopted on the basis of current imaging facilities.

Laparoscopy, used mainly for elective purposes, is increasingly undertaken in emergency settings for certain conditions like appendicitis, peptic perforation and diverticulitis. As a consequence, in trauma settings, laparoscopy has safely been used as a diagnostic tool in patients with equivocal image findings or situations where the mechanism of injury and clinical presentation mandates closer inspection [1]. Yet, after 20 years of experience in the field, surgeons are reluctant to use laparoscopy for definitive treatment in trauma. Understandably, concerns relate to haemodynamic stability of the trauma patient and the ability to safely and expediently perform the necessary therapeutic procedure. While reports of therapeutic laparoscopic (TL) procedures exist [2] no truly comparative study assessing the advantage of TL over laparotomy has been reported in literature. Prospective or randomised trials in trauma settings may be difficult to set up from an ethical and logistic perspective and therefore retrospectively matched comparative studies may be the best way forward to provide evidence for TL in trauma. The aim of this study was to assess whether laparoscopic intervention can be safely performed in trauma and whether there is any overall benefit to the patient.

Methods

The study was designed as a retrospective case control observational study and reported based on *STROBE* recommendations [3]. A retrospective review was undertaken of all surgical procedures within a 10-year period (January 2004–2014) in a major trauma centre. All patients who underwent laparoscopy or laparotomy in a trauma setting were identified by an investigator blinded to the outcomes, through theatre based software containing a prospective database. Each emergency theatre

list, assigned operating code and operative procedure was analysed and crosschecked to identify these patients. Any surgical intervention performed or intended to be performed laparoscopically was considered therapeutic laparoscopy. This term was used interchangeably with "laparoscopy with therapeutic intent". Therefore, in the laparoscopy cohort, patients were excluded where only a diagnostic laparoscopy was conducted. This group was matched with a similar cohort of patients who underwent a laparotomy using propensity score matching. Parameters that were matched included age, sex, markers of haemodynamic status (heart rate, blood pressure and respiratory rate) and Injury Severity Score (ISS). ISS is a validated score for assessing severity of trauma, which divides the human body into nine regions and scores of 1 to 6 are assigned reflecting the severity of injury. ISS is calculated as the sum of the squares of the three most significantly injured body regions. A score of greater than 15 signifies major trauma [4].

For both groups of patients, undergoing laparoscopy or laparotomy patients, operative details, peri-operative outcomes, analgesic use, hospital stay, complications, morbidity, and mortality were compared. Post-operative opioid doses were converted to a morphine equivalent dose based on an equianalgesic table [5]. Post-operative complications were compared based on the well validated Clavien-Dindo classification which is universally used in surgical literature [6].

Statistical analysis

All continuous data were expressed in median values and range. Continuous variables were compared with the non-parametric Mann-Whitney test. A two sided p value of less than 0.05 was considered statistically significant. The statistical package SPSS version 21 was used for analysis.

Results

During the 10-year period, 29 laparoscopies were performed for abdominal trauma, of which 25 were therapeutic in intent. Similarly, 25 out of 106 patients who underwent laparotomy with a therapeutic intent for trauma during the same period were adequately matched for age, sex, parameters of haemodynamic stability, and ISS scores based on propensity matching scores (Table-1.) There was

no missing data in the parameters collated. Patients in both groups were haemodynamically stable.

Five patients in the laparoscopy group needed more than two units of blood transfusion, with a single patient requiring four units of blood transfusion for a ruptured spleen (during and after surgery). In the laparotomy group, four patients needed red blood cell transfusion, with one patient requiring six units of packed cells for a retroperitoneal haematoma. In these patients, blood transfusion was started intra-operatively and they did not become unstable prior to surgery. None of the patients had more than a 1000ml of intra-operative blood loss and the median drop in haematocrit in either group was 2% (0-3.5%).

The overall median ISS score was 16 in each group, indicating major trauma. In the laparoscopy group, blunt trauma to the abdomen was the mechanism of injury in four patients but majority of injuries were penetrating in nature (n= 21) which included one patient with evisceration of small bowel after a knife stab and one gunshot injury. Similarly, in the laparotomy group only two patients suffered blunt abdominal trauma, one swallowed a knife causing perforation of the bowel and the rest 22 penetrating injuries included two gunshot injuries.

Computerised Tomography (CT) scan prior to laparoscopic intervention was performed in 88% (n=23) of patients whereas 84% (n=22) had CT scan prior to laparotomy. In the remaining patients, surgical intervention was planned on the basis of clinical findings and/or radiograph and focused abdominal ultrasound in trauma (FAST) findings. The distribution of operative procedures was similar in both groups and ranged from more complex procedures like repair or resection of bowel, splenectomy and diaphragmatic repair to simpler interventions like excision of omentum for omental injury and washout of large haematomas (Table-2.) Splenectomy was performed after conservative treatment failed in one patient and for a large haematoma with grade 3 injury and active bleeding in the second patient.

Operating time did not differ between the two groups (105 vs 98 minutes, $p>0.05$). One patient in the laparoscopy group was converted to an open procedure. The patient had a perforated stomach with a non-expanding retroperitoneal haematoma. While the stomach was repaired laparoscopically, it was felt that a closer inspection by laparotomy was warranted to exclude other retroperitoneal injuries and be certain that further intervention was not required. Opioids were significantly less required in laparoscopy patients (34 vs 136 meq, $p<0.05$). Six patients (24%) in each group needed post-operative intensive care unit (ITU) admission, but overall hospital stay was statistically significantly less in the laparoscopy patients (4 vs 9 days, $p<0.05$). Overall post-operative complications were minor (Clavien Dindo $< IIIa$) for both groups, but statistically significantly higher in the laparotomy group ($p=0.02$) (Table-3). There were no severe complications (Clavien-Dindo IIIb-V) or mortality in either group.

Discussion

The role of laparoscopy in trauma is controversial. Concerns of missed injuries (41-77%) in early studies [7] led to widespread scepticism. Recent studies are a testimony to improved techniques and experience which now suggest that missed injuries are less than 1%. [1, 8] As a result, diagnostic capabilities of laparoscopy in trauma are no longer in doubt. In fact, a current review confirms that diagnostic laparoscopy (DL) significantly reduces non-therapeutic laparotomy by about 52% [1]. But management guidelines of most trauma centres limit the role of laparoscopy only to a diagnostic tool in trauma [9-12] and the jury is still out on the effectiveness of therapeutic laparoscopy (TL) in trauma. The reluctance to perform TL in unstable patients is understandable as precious time could be lost in gaining access to the site of active bleeding. There also remains a concern on the potential adverse effect of pneumoperitoneum on cardiovascular physiology of an unstable trauma patient. However in haemodynamically stable patients, TL may still have a role. This is the first matched comparative study focusing on laparoscopy for therapeutic purposes which suggests that TL is safe in stable patients and more beneficial than a laparotomy in trauma.

ACCEPTED MANUSCRIPT

In 1976, the first laparoscopy performed in trauma was done in aid of diagnosis [13]. But only in the last 20 years, evidence reporting the feasibility of TL in stable patients has emerged [12, 14-16]. A review of these studies reveals that TL was attempted in 24% (145/590) of patients with detected intra-abdominal injuries and a reported conversion rate of about 12%. Diaphragm was most commonly repaired (54%) followed by omentum /mesentery (13%), liver (13%),stomach (7%), small bowel (5%),colon (3%) and spleen (3%) [1]. The slow uptake of TL in trauma was also evident in the largest series till date, a retrospective analysis of a National Trauma database in USA of 4755 trauma patients undergoing diagnostic laparoscopy of which only 19% (916) had a therapeutic intervention while 20% proceeded to a laparotomy. TL was successful in all cases. Laparoscopic repair of diaphragmatic injury (19%), gastrostomy (14%), repair or resection of small (15%) or large bowel (13%), repair of liver laceration (5.3%), splenectomy (5.2%), and control of mesenteric bleeding (4%) was carried out [17]. In our study, TL was performed for a similar spread of intra-abdominal injuries which included bowel repair or resection (n=10, 40%), liver injury (n=3, 12%), omental/mesenteric injury (n=3, 12%), washout of haematoma (n=7, 28%),splenectomy (n=2,8%) and one diaphragmatic injury.

Comparative studies in trauma tend to focus on the benefits of laparoscopy over conventional laparotomy irrespective of whether laparoscopy was for diagnostic or therapeutic purposes. The cohort of DL patients confounds any advantages seen and probably do not allow accurate assessment of a benefit of TL compared to laparotomy. Lin et al retrospectively compared 38 laparotomy patients to 48 patients laparoscopy patients including diagnostic (31 patients) and therapeutic interventions (17 patients) and concluded that laparoscopy reduces non-therapeutic laparotomy[12]. Khubutiya et al compared 280 laparotomy to 160 DL and 58 TL patients with unmatched injury severity scores (<15) indicative of non- major trauma and suggested that opioid requirements and post-operative complications were less with laparoscopy. TL was not separately compared with laparotomy [18]. Similarly another recent retrospective study tested a new management algorithm in

trauma which included laparoscopy by comparing 47 historic laparotomy patients to 57 urgent laparoscopy patients (including 9 DL and 48 TL) and also concluded that laparoscopy decreased laparotomy rates without affecting post-operative complications [19]. While this may prove the efficacy of their newly adopted algorithm, comparing patients from different time periods and inclusion of DL patients makes it impossible to extrapolate the advantages of TL over conventional laparotomy. But our study was designed to compare TL with laparotomy by identifying two matched haemodynamically stable cohorts who had incurred major trauma (Injury severity score >15) and is perhaps the most appropriate study in literature till date, to actually address the advantages of TL over laparotomy. The benefits of elective laparoscopic surgery compared to traditional laparotomy are well documented in literature. Decreased pain, reduced hospital stay, faster functional recovery, better cosmesis are desirable advantages offered by laparoscopy which improves overall patient care. Our results confirm that TL does not take longer to perform than a laparotomy, has a low conversion rate (1/25) and has the benefit of significantly decreasing post-operative opioid requirements and hospital stay without difference in morbidity.

In the UK, NICE guidelines for major trauma are still under consideration but each major trauma centre has developed their own protocol based on local experience and resources. In this study, CT appeared to have 100% sensitivity as intra-abdominal injuries were all identified when CT was performed. Retroperitoneal colonic injuries are better seen on imaging than laparoscopy but some other injuries like diaphragmatic and small bowel injuries can be difficult to detect on imaging. CT complements diagnostic laparoscopy and helps in the process of decision making. Over the years, CT has increasingly been performed on haemodynamically stable patients prior to laparoscopy to evaluate retroperitoneal structures and identify situations that might require intervention radiology.

In our institute, decision for performing laparoscopy or laparotomy was dictated by the experience of the operating surgeon. Laparoscopy was performed systematically to avoid missing injuries. The

entire small bowel was assessed by graspers sequentially from the terminal ileum to the duodeno-jejunal flexure. The diaphragm, liver, spleen and colon were carefully inspected. While the retroperitoneum was well assessed by CT, on laparoscopy, both paracolic gutters were inspected but right and/or left colon was mobilised only if there was a suspected injury. Central compartment is normally assessed after a left-sided medial visceral rotation but is rarely needed in haemodynamically stable patients. The duodenum could easily be examined after Kocherisation and suspected gastric injuries were further confirmed by an on-table methylene blue dye test. After identifying the injuries, additional ports were placed according to the procedure required. Tilting of the table to the surgeon's advantage can be very helpful in performing several laparoscopic manoeuvres especially for moving bowel out of harm's way or for adequate washout or suction. Competent intra-corporeal suturing is a necessary skill for all repairs especially of the small bowel, stomach and diaphragm. Colonic injuries were laparoscopically managed by primary repair (n=3), primary repair with colostomy (n=1) and a Hartmann's procedure (n=1). Easy availability of gastrointestinal and vascular stapling devices and energy devices at all times of the day was essential. This was required for small (n=2) and large bowel resections (n=5), control of liver injuries (n=3) and control of short gastric vessels and splenic hilum for splenectomy (n=2).

Limitations of this study stem from the obvious retrospective nature of the study. Despite matching the patients, the procedures performed in each group were not exactly identical. Small numbers and variability of experience of the operating surgeon are additional factors. Prospective comparative studies are difficult to design due to low numbers of trauma cases requiring surgical intervention. On the other hand, various haemodynamic parameters were well matched. Injury severity scores suggesting major trauma (>15) in this study increases its clinical relevance. This is the only study directly comparing TL with laparotomy in a trauma setting.

In spite of the safety and feasibility of performing TL, careful consideration should be taken before recommending TL over laparotomy in trauma. The morbidity associated with a laparotomy can be as high as 41% and lead to increased hospital costs [20, 21]. In this study, post-operative complications, although minor, were greater in the laparotomy group. TL can help avoid such morbidity. On the contrary, patient safety is of paramount importance and should not be compromised by laparoscopic experiments. All studies with one exception [22] believe that laparoscopy should be contraindicated in haemodynamically unstable patients. Laparoscopy is also not advisable in patients with severe traumatic brain injury as intracerebral pressure is known to increase with raised intra-abdominal pressure which has potential to cause further brain damage.[23] It should not be performed by inexperienced surgeons or in centres without easy access to necessary equipment or devices. Therefore the role of laparoscopy should extend to therapeutic intervention in trauma in stable patients but preferably by experienced laparoscopic surgeons working in major trauma centres. Trauma surgeons should receive training in laparoscopy in trauma. Decision making could be based on an algorithm followed in our practice which combines the merits of imaging and diagnostic laparoscopy and takes into account the experience of the surgeon. (fig 1)

In conclusion, minimally invasive surgery does offer several advantages compared to traditional open surgery and should be considered as an additional tool in the trauma surgeon's armamentarium in the care of select trauma patients.

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Table-3: Outcomes

Parameters	Laparoscopy	Laparotomy	P values
Operating time (min)	105 (26-330)	98 (39-308)	0.5
Opiate use (MEQ)	34 (0-289)	136 (23.5-821)	0.002
Complications* (total number)	1 (0-2)	10 (0-3a)	0.02
Stay (Days)	4 (1-16)	9 (2-32)	0.03

All continuous data in median (range)

* Number of complications is a continuous variable allowing Mann-Whitney test to be performed

Table-1 Patient Characteristics

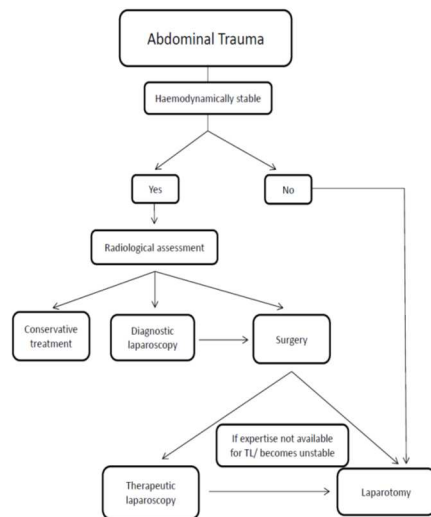
Parameters	Laparoscopy	Laparotomy	P values
Age (years)	33 (14-62)	26 (16-58)	0.23
Sex (male : female)	21:4	23:2	0.41
ISS	16 (4-34)	16 (3-29)	0.35
Heart Rate	102 (67-132)	86 (53-130)	0.08
Blood pressure (mm of Hg)			
– Systolic	130 (96-171)	125 (86--154)	0.75
– Diastolic	85 (41-124)	80 (49-111)	0.8

All continuous data in median (range), ISS= Injury severity score

Table-2 Type of injuries

Parameters	Laparoscopy (n=25)	Laparotomy (n=25)	P values[#]
Bowel repair/resection	10	16	NS
Small bowel	2	10	
Colon	5	3	
Stomach	3	3	
Haematoma washed out	6	5	NS
Omentum excised*	2	1	NS
Splenectomy	2	0	NS
Liver injury	3	2	NS
Diaphragmatic repair	1	1	NS
Mesenteric tear	1	0	NS

* Excision for omental injury or necrosis; [#] NS= not significant



Highlights

- Laparoscopic therapeutic surgery in stable trauma patients is controversial.
- Laparotomy and laparoscopy with definitive surgery were matched and compared.
- Laparoscopy for definitive treatment was safe in abdominal trauma
- Laparoscopy is less morbid, painful and shortens hospital stay.
- Therapeutic laparoscopy leads to improved care in stable trauma patients.